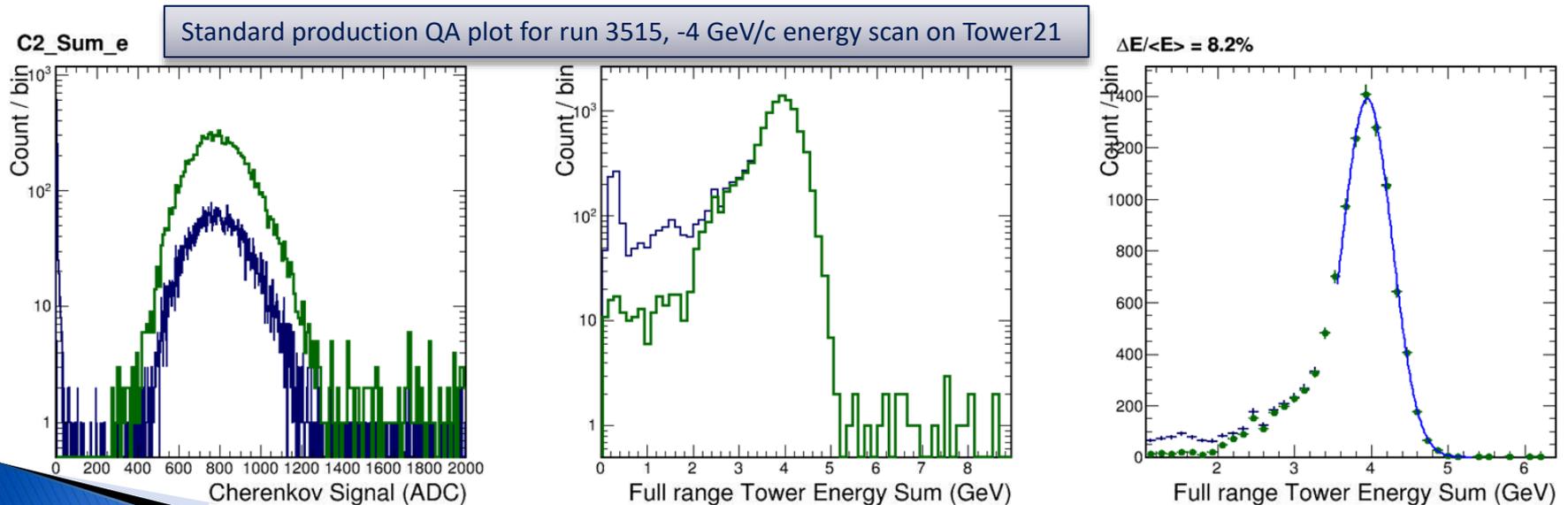
A 3D cutaway diagram of a particle detector, likely the EMCal at PHENIX. The diagram shows various internal components in different colors: red, blue, green, yellow, and purple. A central horizontal beam pipe is visible. The detector is mounted on a complex support structure.

Prototype-3 EMCal data check

Jin Huang (BNL)

Second energy scan started last night

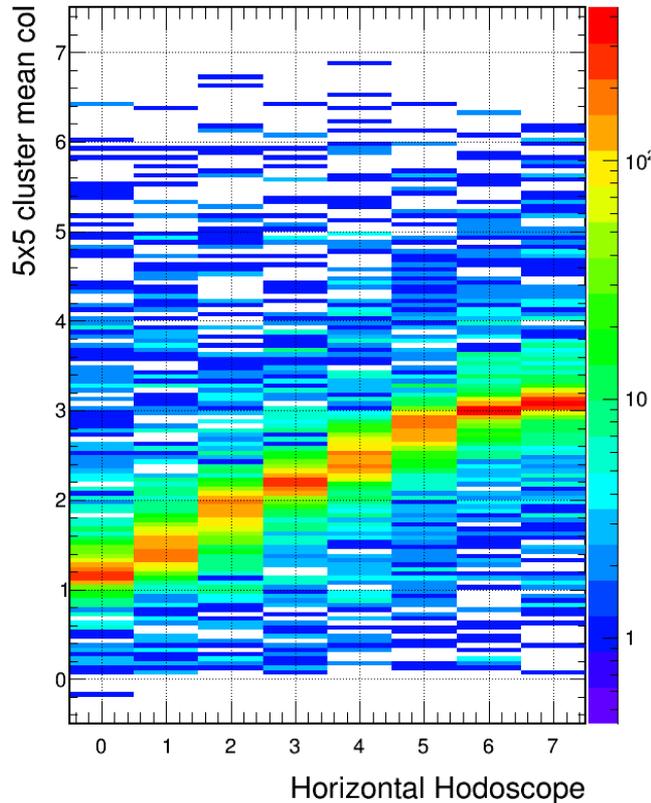
- ▶ Improvement over 1st-energy scan (not-analyzable)
 - Fix EMCal “gain” problem
 - Amplified Cherenkov signal so in similar range as last run
 - 3-energy point taken on tower 21 so far before beam problem
- ▶ Private test production with Mike’s MIP calibration:
`/gpfs/mnt/gpfs02/sphenix/sim/sim01/phnxreco/users/jinhuang/SPHENIX_work/Prototype_2017/Production_0130_WithEMCalCalib`
- ▶ Once MIP calibration finalize with simulation correction, plan to release official production and tutorial to the list
- ▶ Analysis code for this talk:
 - Analysis module: <https://github.com/SPHENIX-Collaboration/analysis/tree/master/Prototype3/EMCal/ShowerCalib>
 - Plotting macro: <https://github.com/SPHENIX-Collaboration/analysis/blob/master/Prototype3/EMCal/macros/DrawPrototype3ShowerCalib.C>



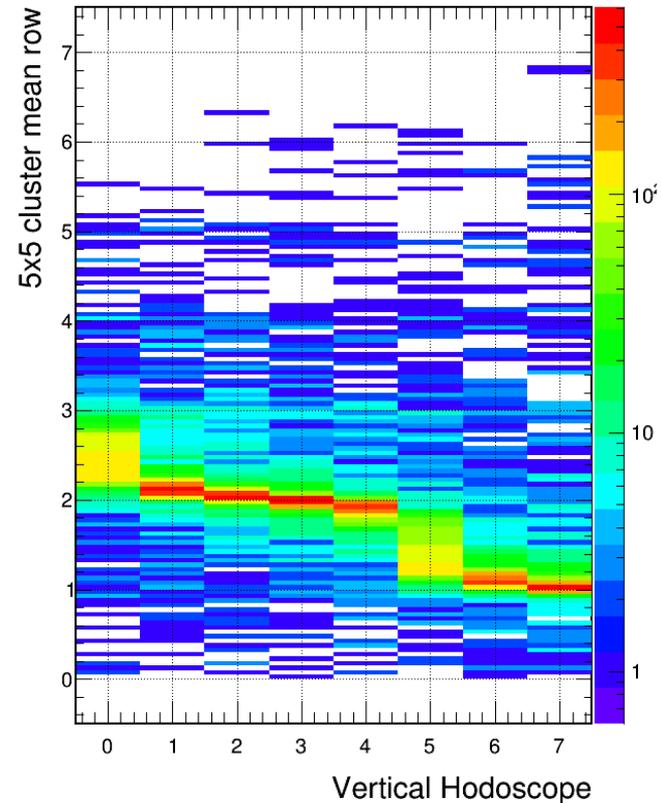
beam_00003515-0000_DSTReader.root_DrawPrototype3EMCalTower_EMCDistribution_SUM_Energy_Sum_CEMC_C2_Sum_e_Valid_HODO_Trigger_VETO.png

Hodo scope checks – nice correlation

Horizontal hodoscope check

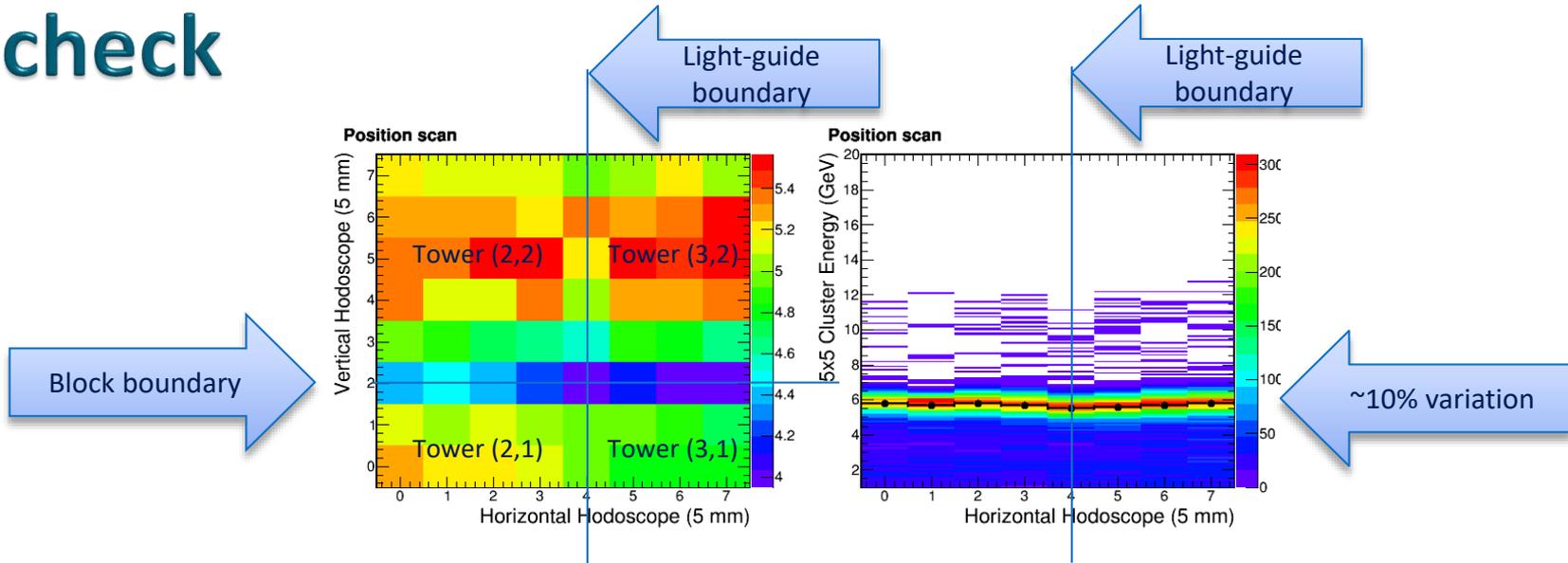


Vertical hodoscope check

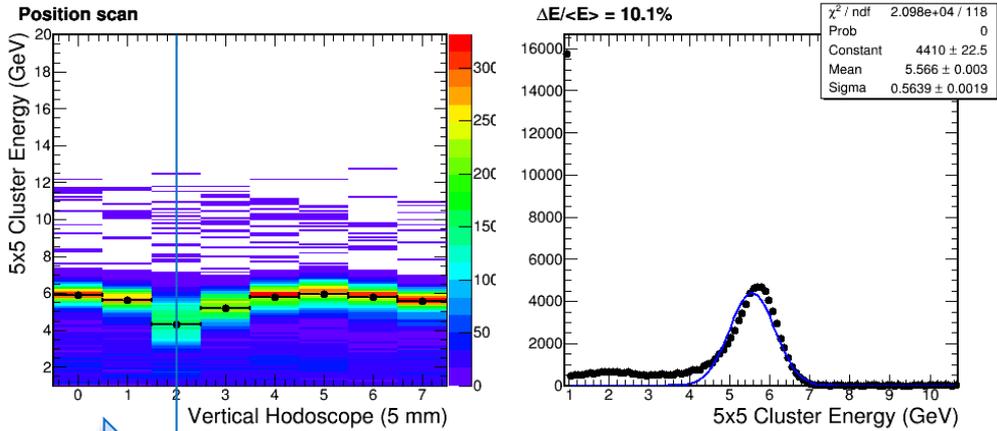


Run 3514-3516, -2 to -6 GeV/c energy scan on Tower21

Position dependent energy response check



- Cuts:
- MIP calibration
 - 5x5 cluster energy with max energy response
 - C2 Cherenkov sum>500
 - Veto counters<15
 - Single horizontal and vertical hodoscope finger>30



Block boundary, ~30% variation

Run 3514, -6 GeV/c energy scan on Tower21, cut on electrons

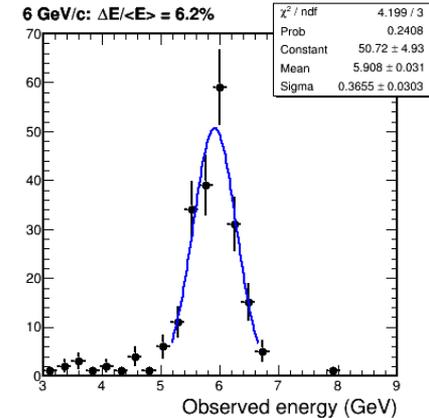
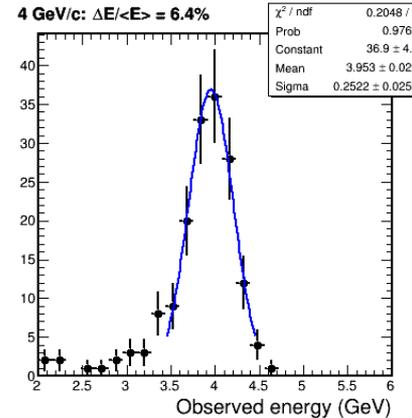
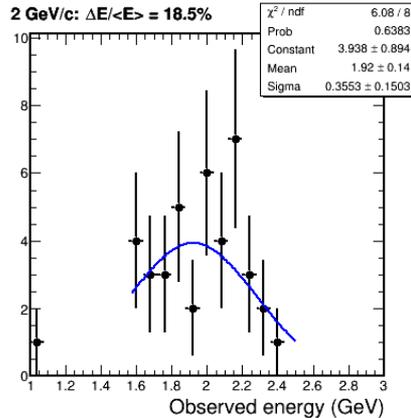


Electron line-shape for tower 21

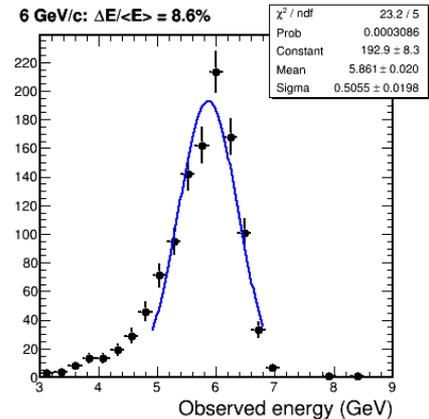
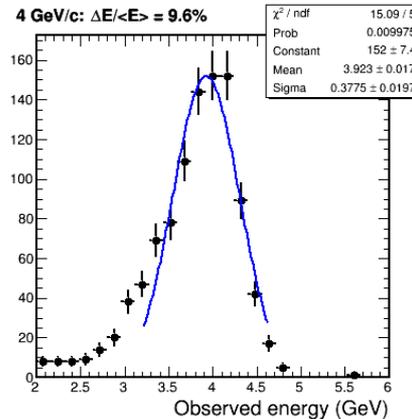
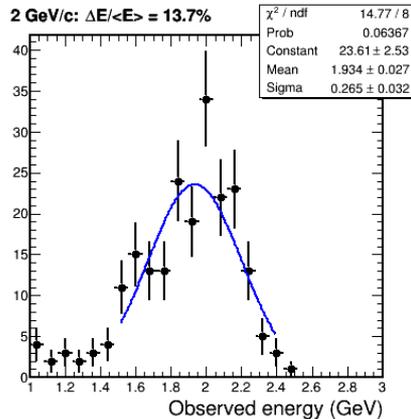
Cuts:

- MIP calibration
- 5x5 cluster energy with max energy response
- C2 Cherenkov sum>500
- Veto counters<15
- Single horizontal and vertical horoscope finger>30

Center 1x1 hodoscope cut @ (h=3, v=3)



Center 2x3 hodoscope cut



Resolution check so far for tower 21

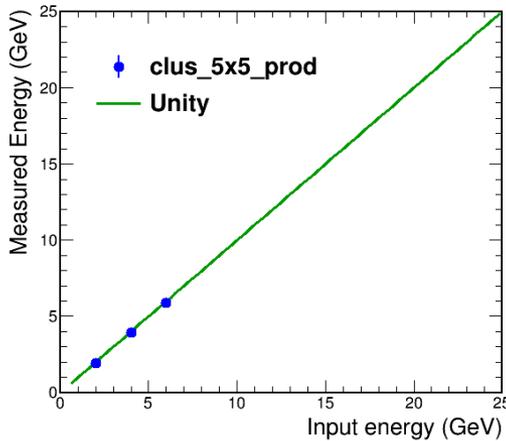
Cuts:

- MIP calibration
- 5x5 cluster energy with max energy response
- C2 Cherenkov sum > 500
- Veto counters < 15
- Single horizontal and vertical hodoscope finger > 30

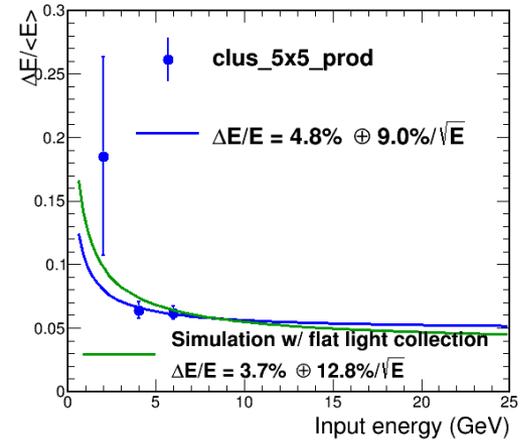
- ▶ So far center tower response consistent with simulation with flat light response
- ▶ Observe effects of position dependence when using 2x3 hodoscopes

Center 1x1 hodoscope cut @ (h=3, v=3)

Electron Linearity

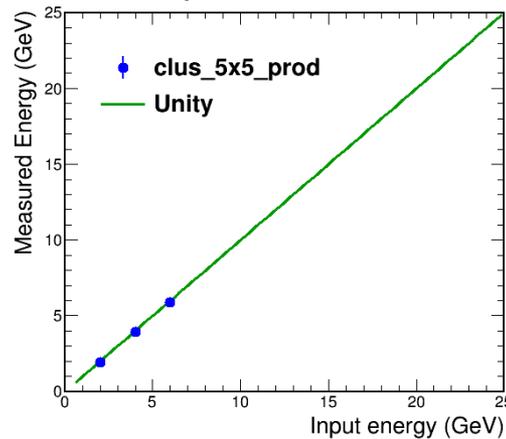


Electron Resolution

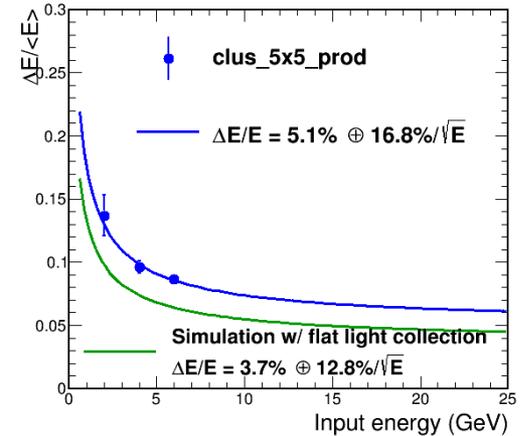


Center 2x3 hodoscope cut

Electron Linearity



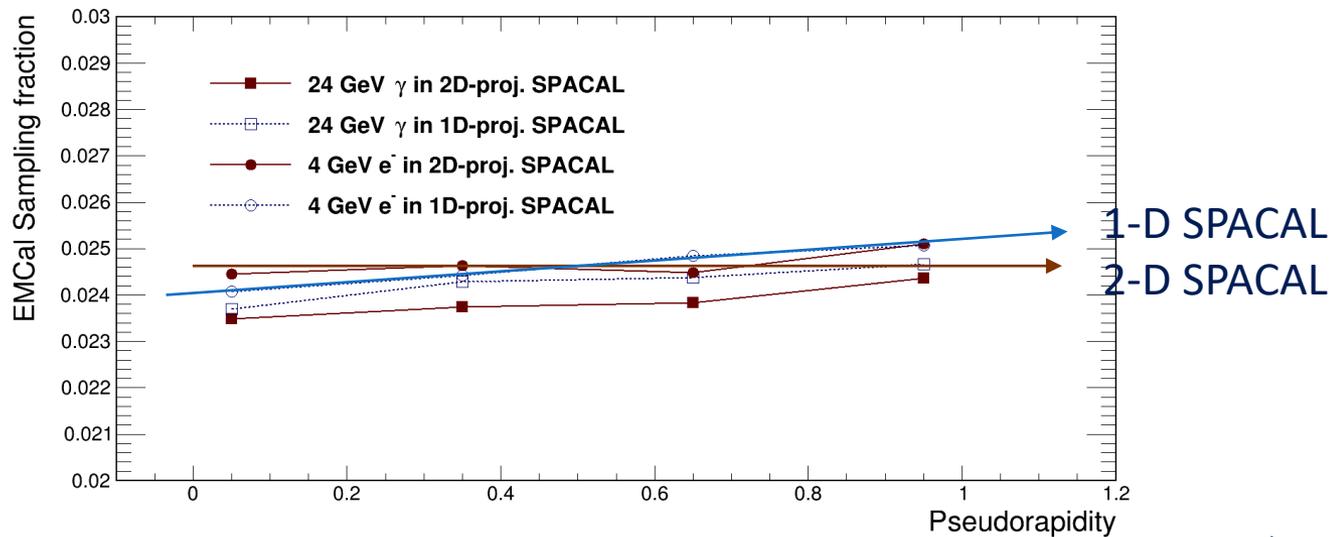
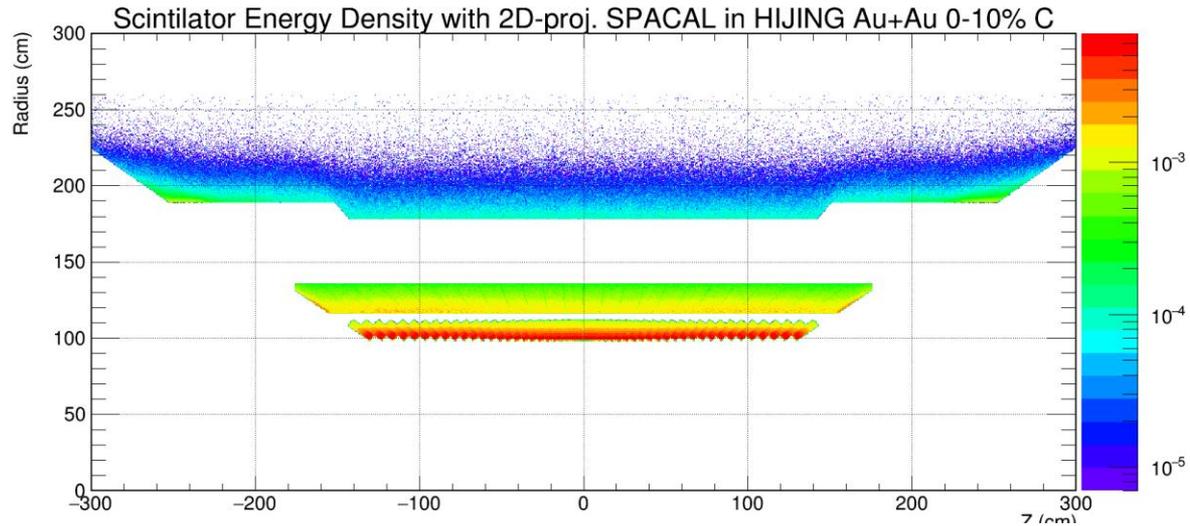
Electron Resolution



Extra information



Expectation from sPHENIX pre-CDR simulations: Sampling fraction

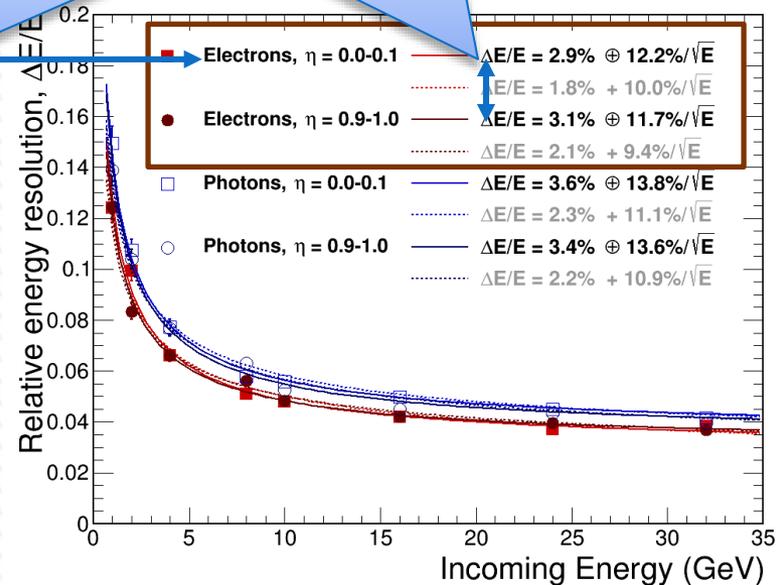
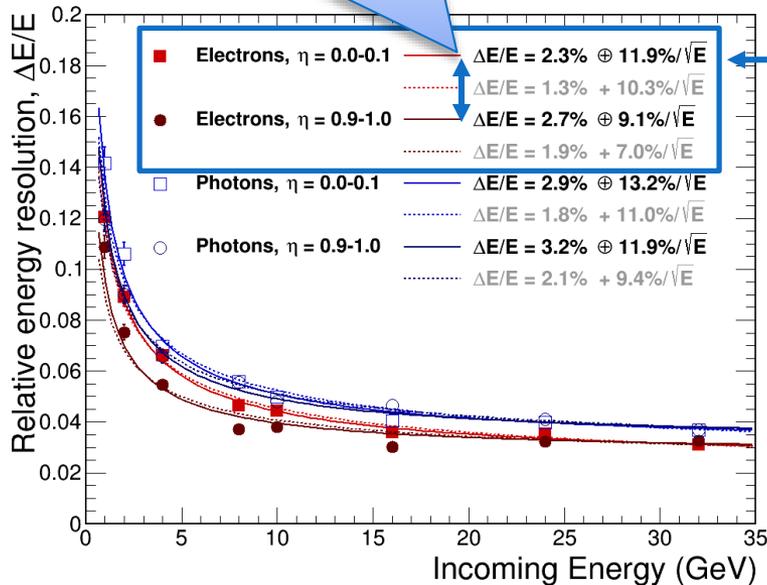


Expectation from sPHENIX pre-CDR simulations: Resolution

Significant improve in stat. term from High sampling fraction and frequency

Larger constant term expected from Variation in sampling fraction VS depth

Consistent performance between forward And central blocks



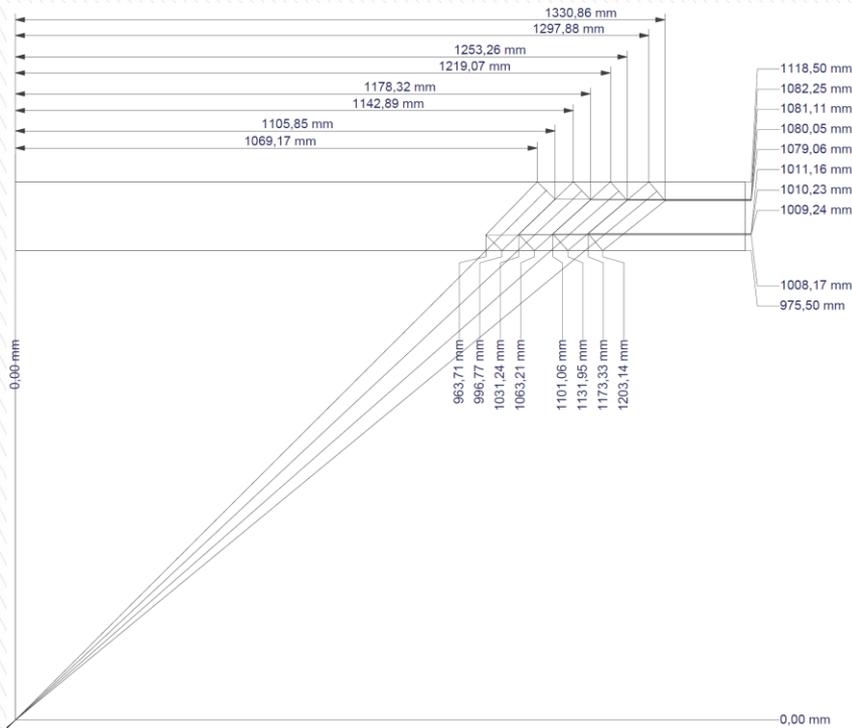
1D SPACAL, No SVX,
Pedestal noise (2ADC), photon fluctuation
(500e/GeV)

2D SPACAL, No SVX,
Pedestal noise (2ADC), photon fluctuation
(500e/GeV)

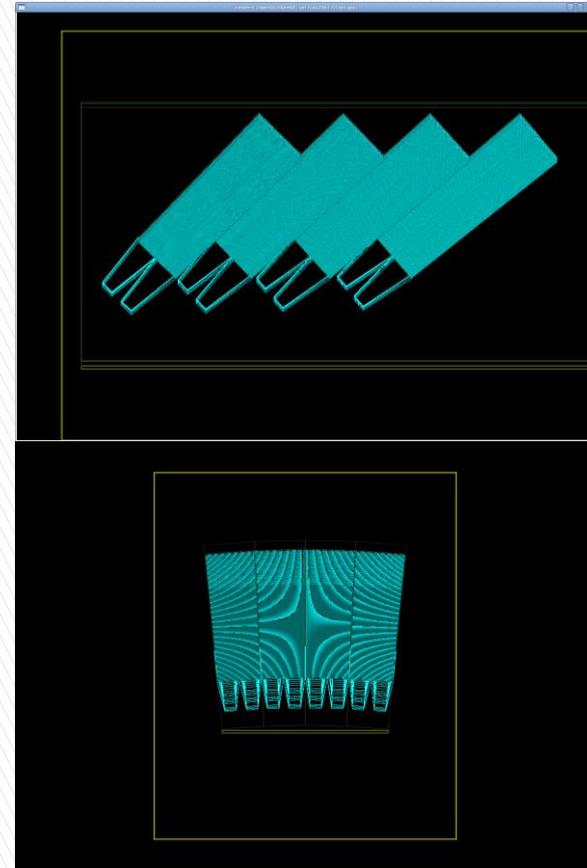
Prototype3 EMCal -> sPHENIX simulation

- ▶ Introduced by three pull request:
 - <https://github.com/sPHENIX-Collaboration/macros/pull/44>
 - <https://github.com/sPHENIX-Collaboration/coresoftware/pull/231>
 - <https://github.com/sPHENIX-Collaboration/calibrations/pull/17>
- ▶ Single macro to run (after nightly build):
 - https://github.com/sPHENIX-Collaboration/macros/blob/master/macros/prototype3/Fun4All_G4_Prototype3.C

From drawing to simulation

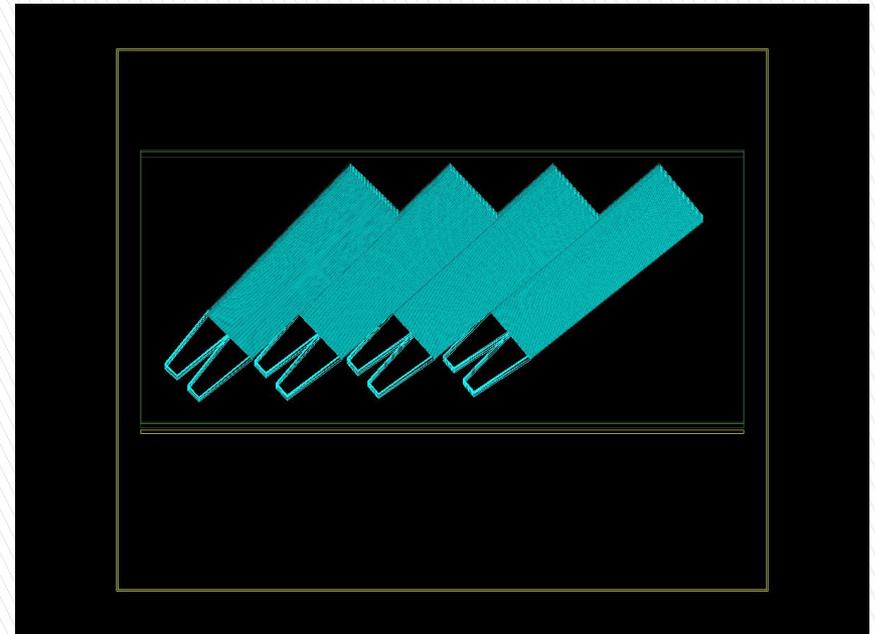
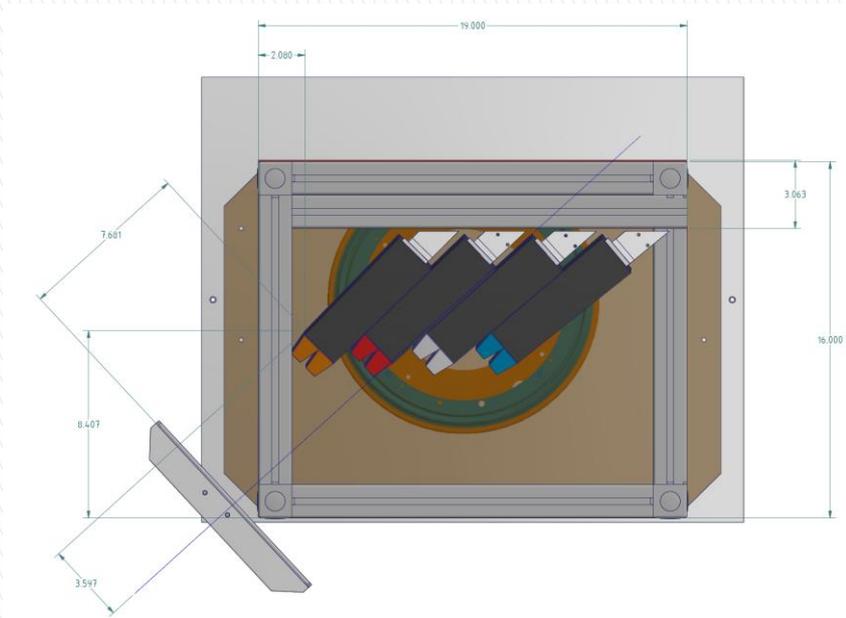


Drawing - Block size



Geant4 simulation

From drawing to simulation

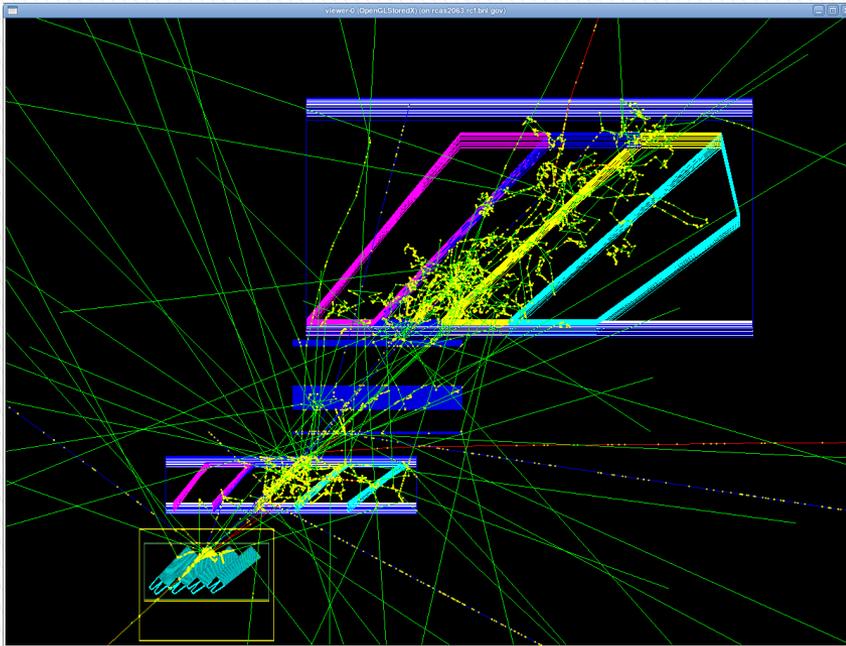


Drawing – Module in enclosure

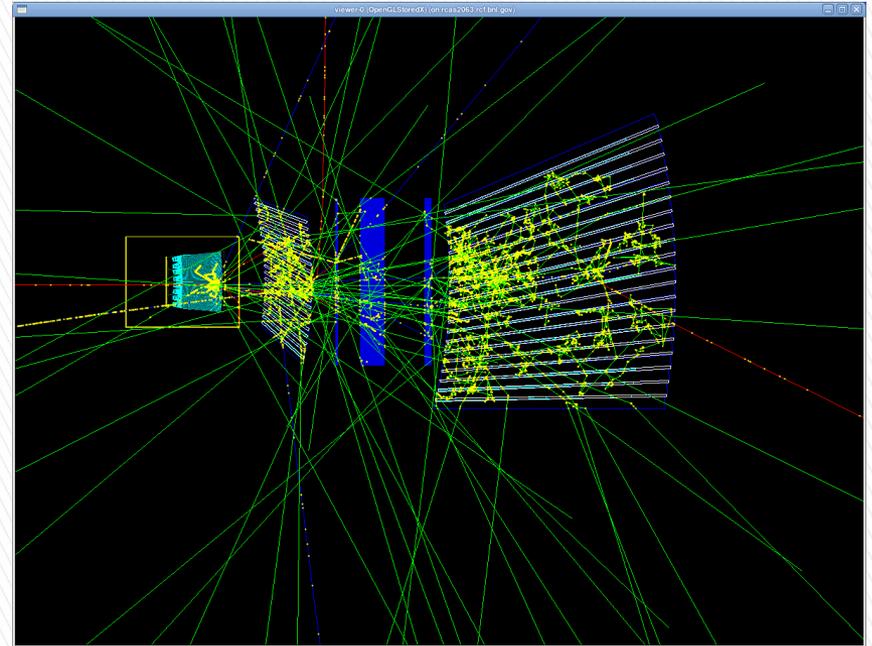
Geant4 simulation

Put it all together

– “typical” Simulation 32 GeV pion



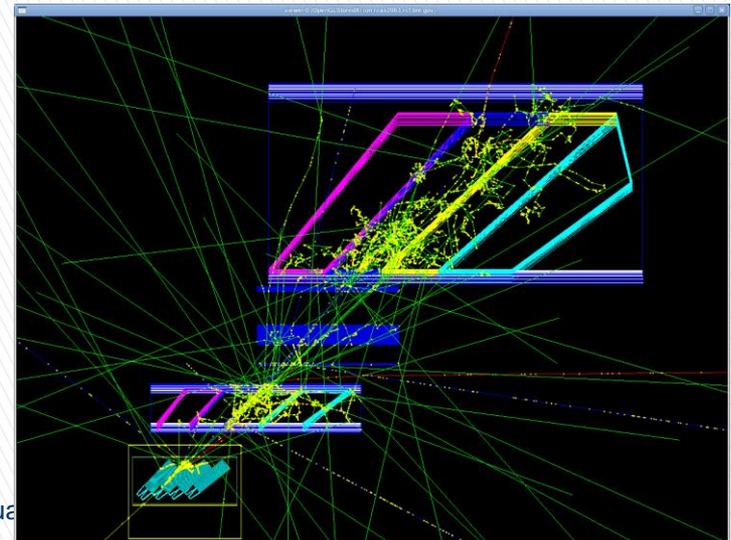
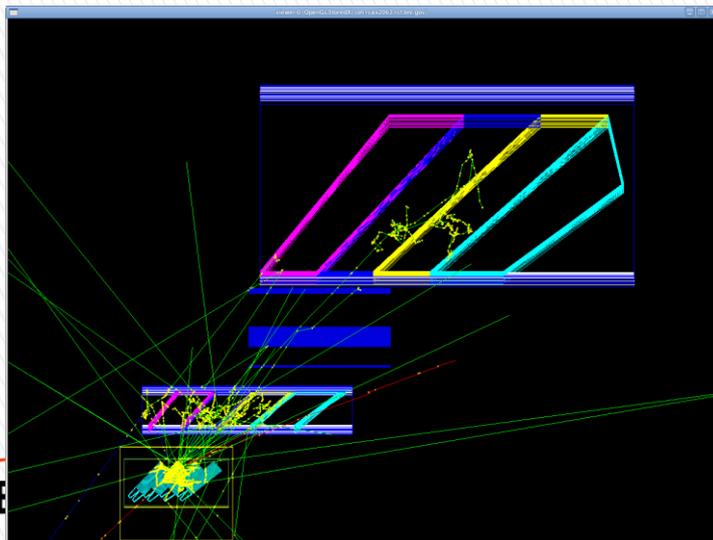
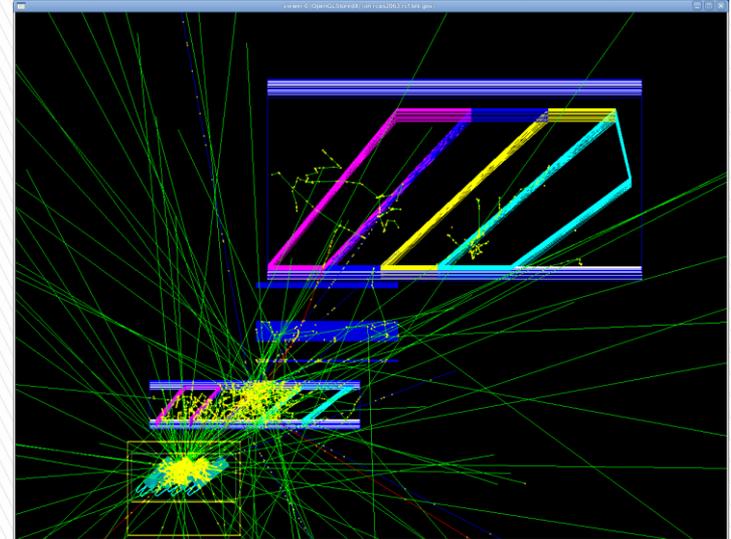
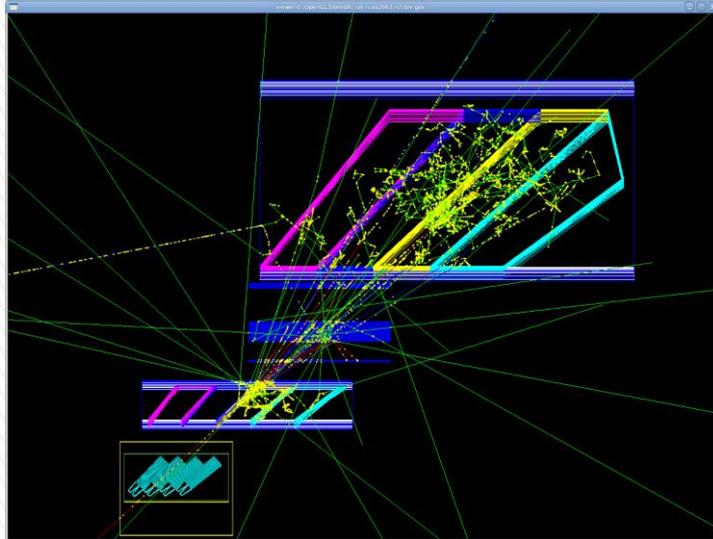
Simulation Top View



Simulation Side View

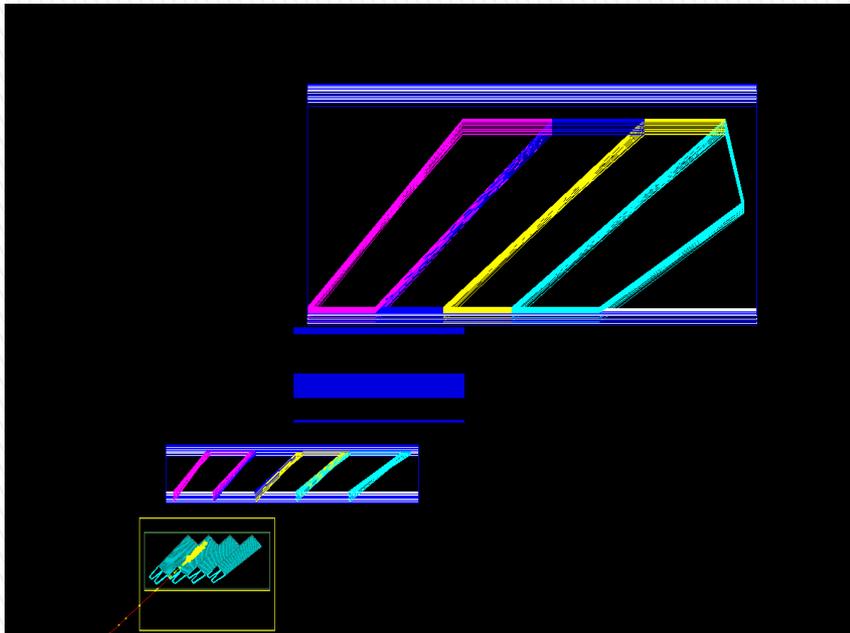
Put it all together

- What most event looks like

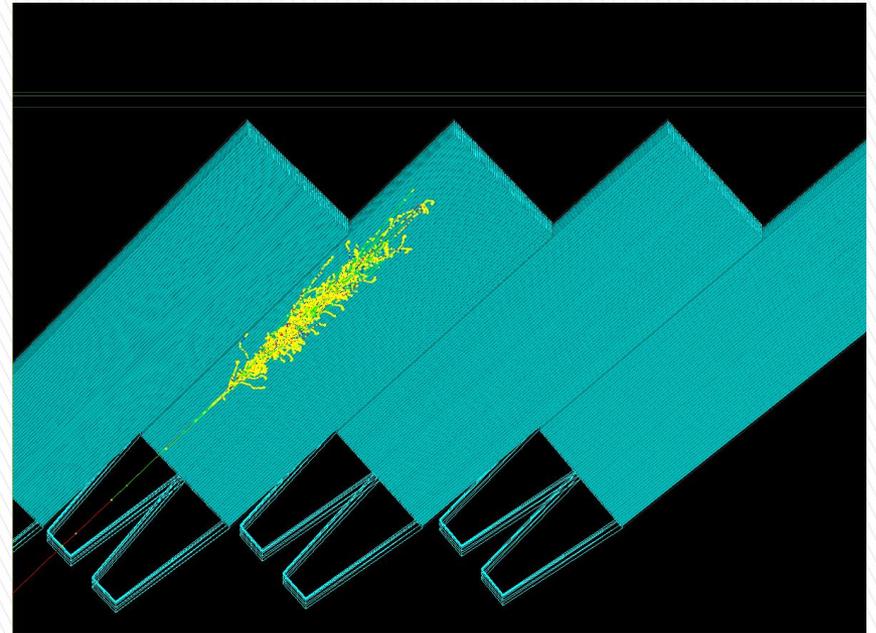


Put it all together

- “typical” Simulation 32 GeV electron



Simulation Top View



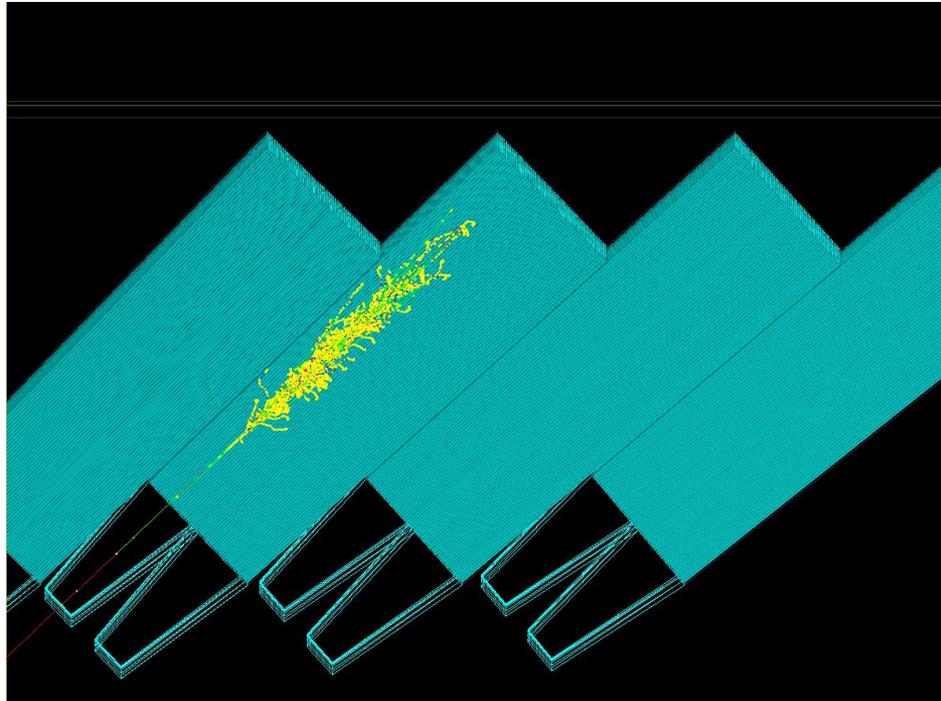
Simulation EMCal View

Performance checks

- <https://github.com/sPHENIX-Collaboration/macros/pull/44>
- <https://github.com/sPHENIX-Collaboration/coresoftware/pull/231>
- <https://github.com/sPHENIX-Collaboration/calibrations/pull/17>

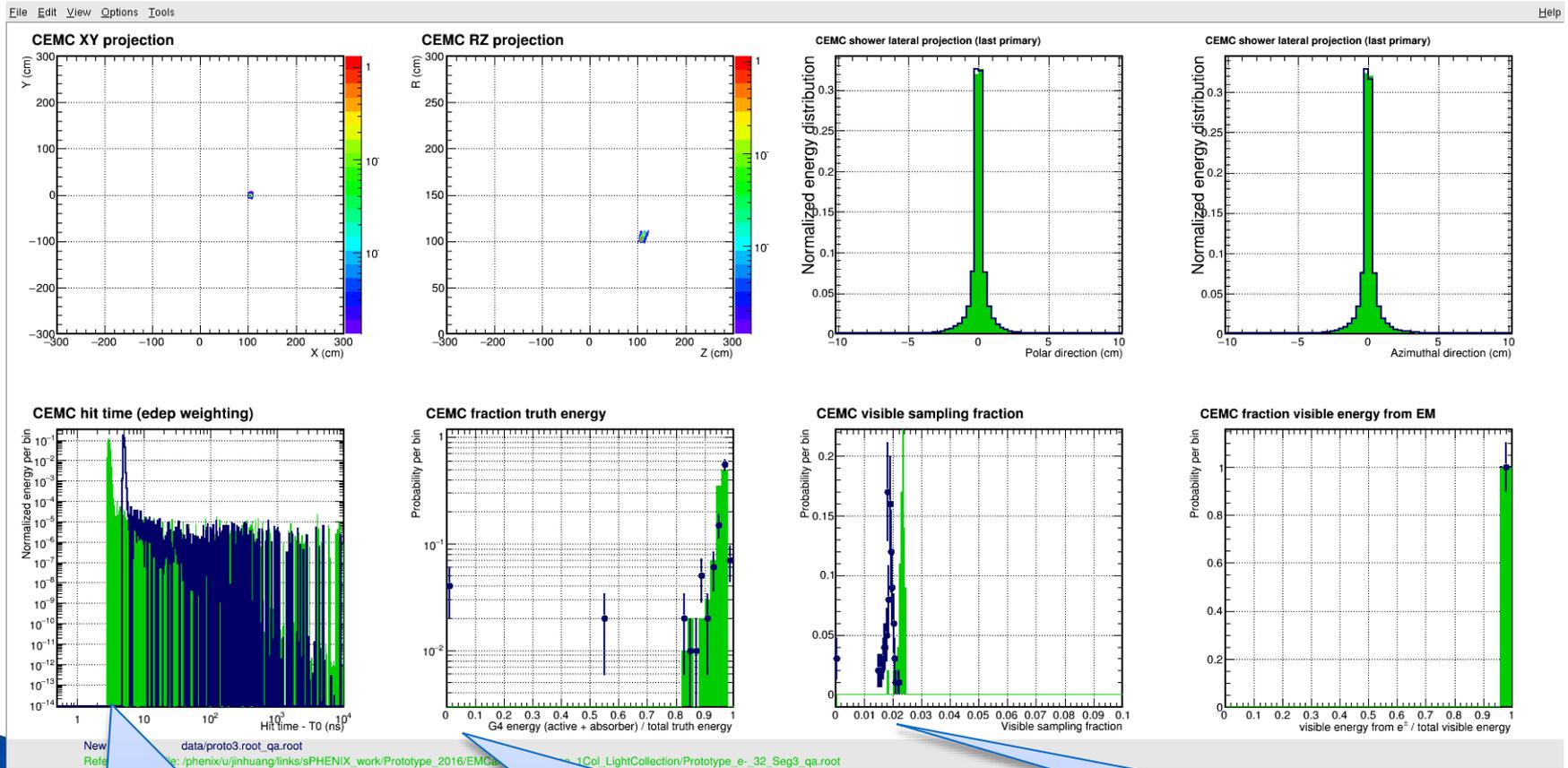
Configuration1 simulated

- ▶ Flat light collection efficiency
- ▶ Shoot to edge between two towers
- ▶ Tilt EMCal 0 degrees vertically



Standardized quality checks

Data point : Prototype3, 32 GeV electron, 0-degree tilt (Configuration1)
 Shade: Prototype2 , 32 GeV electron , 0-degree tilt



Longer flight path $R/\sin(\theta)$
 → later hit time by a few ns

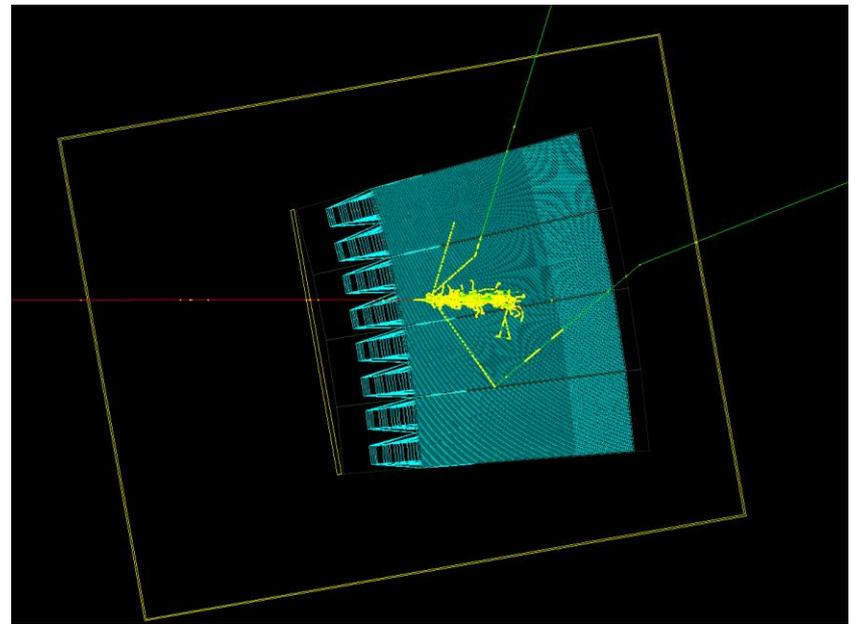
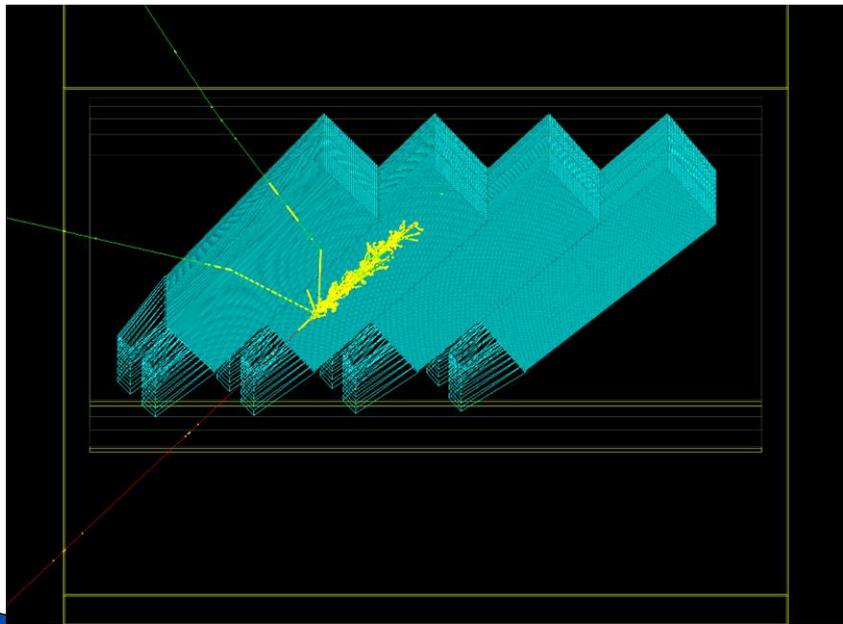
Some leakage due to choice of indenting angle
 (Particle goes through exact gap between blocks)

Signification lower sampling fraction!!
 Prototype 3 has 15% less fiber than pre-CDR



Configuration2 simulated

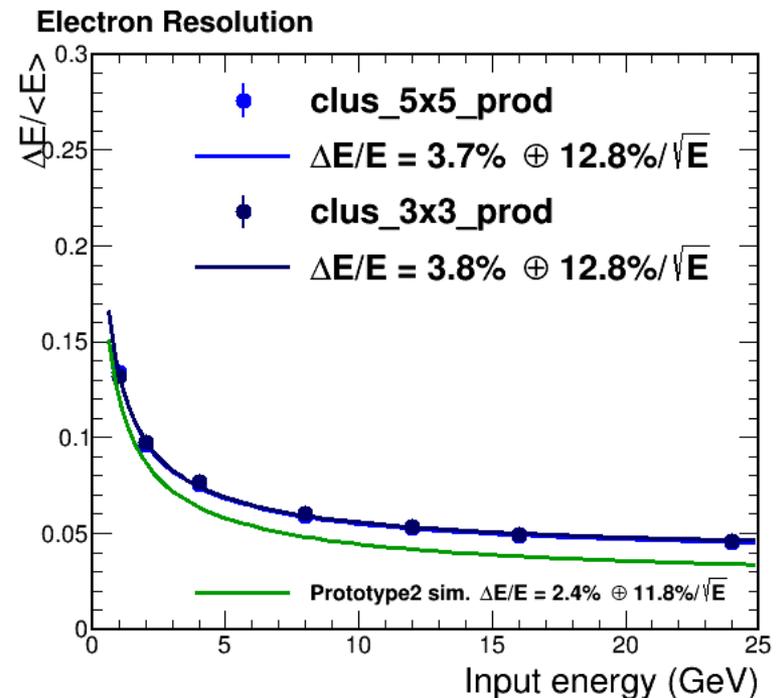
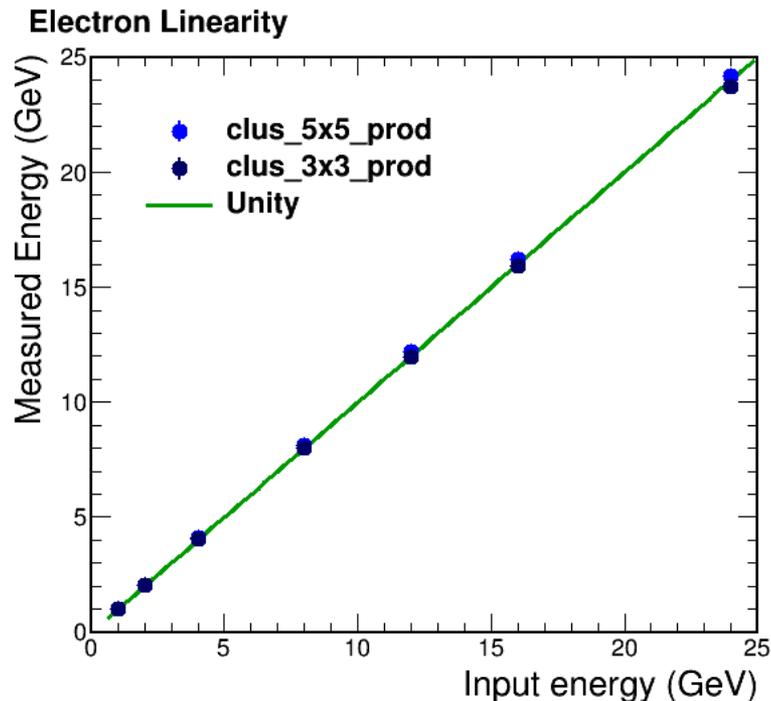
- ▶ Flat light collection efficiency
- ▶ Shoot to center of one tower
- ▶ Tilt EMCal 10 degrees vertically ← add in a tilt avoid perfect-geometry channeling



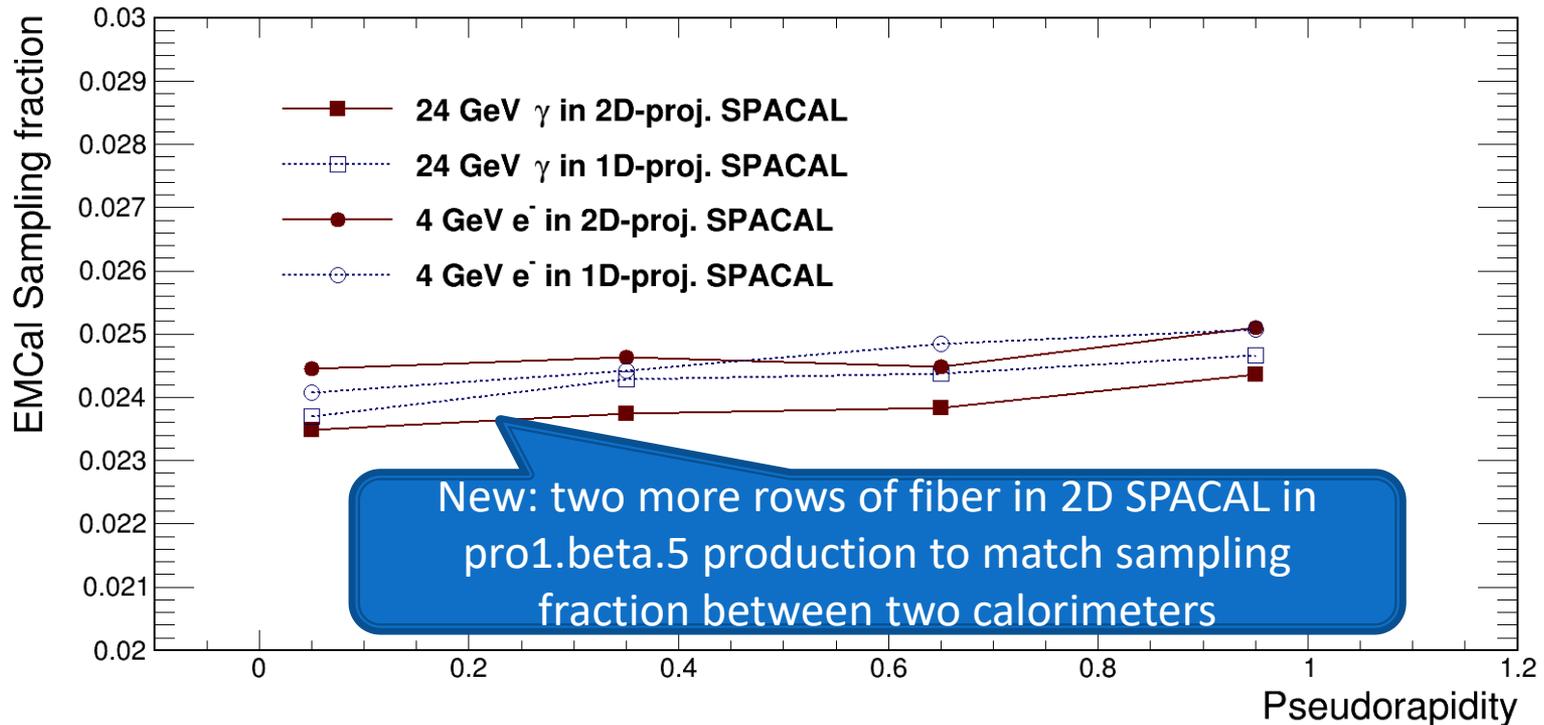
Configuration2 simulation result

- ▶ Prototype3 are expected to have higher intrinsic stat. and constant terms:
- ▶ 15% less fiber leads to increase of stat. term from 11.8% -> 12.8%
- ▶ Some composition of less fiber and expected sampling fraction variation leads to constant term from 2.4% -> 3.7%

File Edit View Options Tools Help



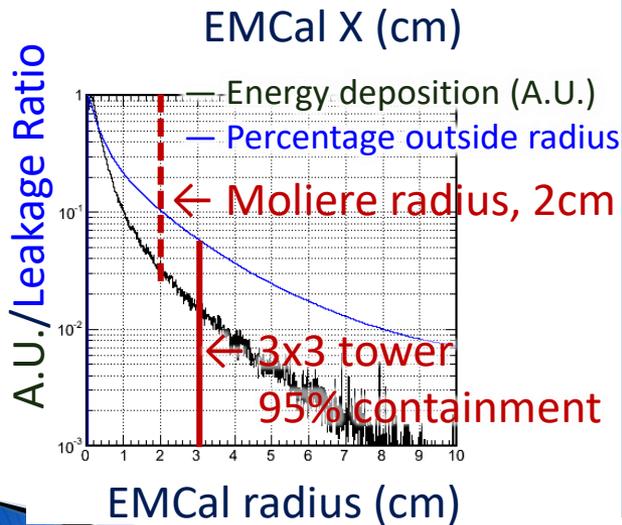
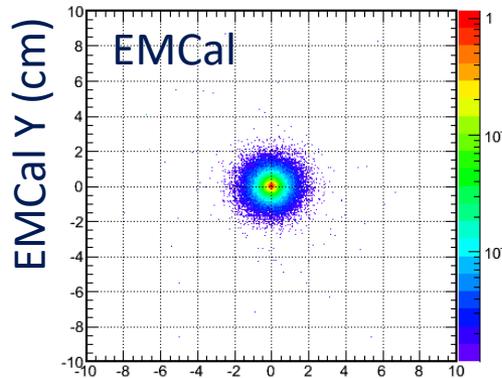
Sampling Fraction



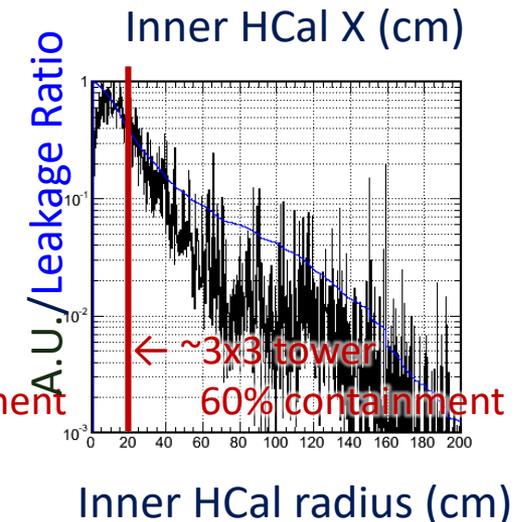
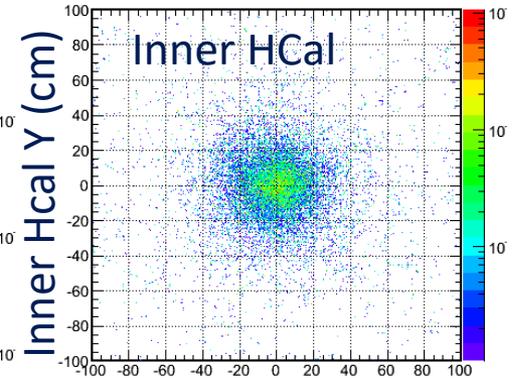
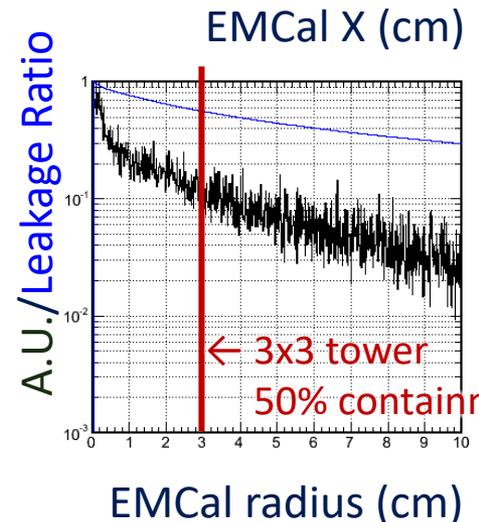
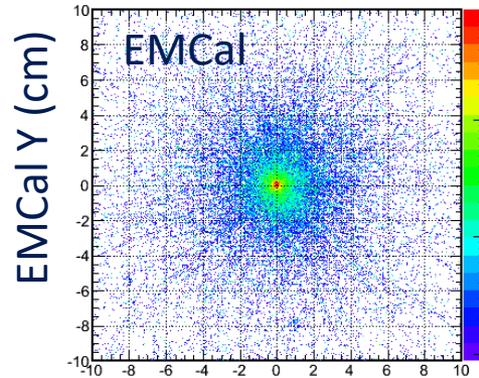
/direct/phenix+sim02/phnxreco/ePHENIX/jinhuang/sPHENIX_work/single_particle/DrawEcal_DrawSF.pdf

Lateral extension of shower

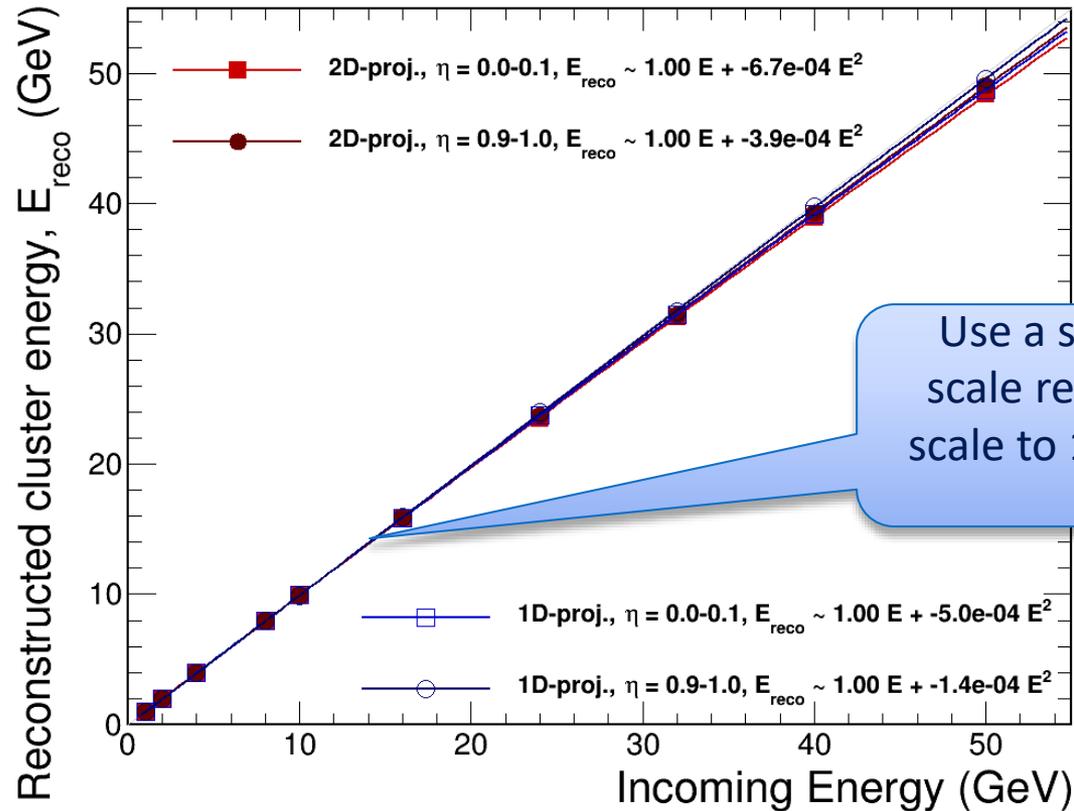
4 GeV Electrons



4 GeV Pions, that passed E/p electron-ID cut



Linearity – double checking



Energy resolution VS test beam

Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)

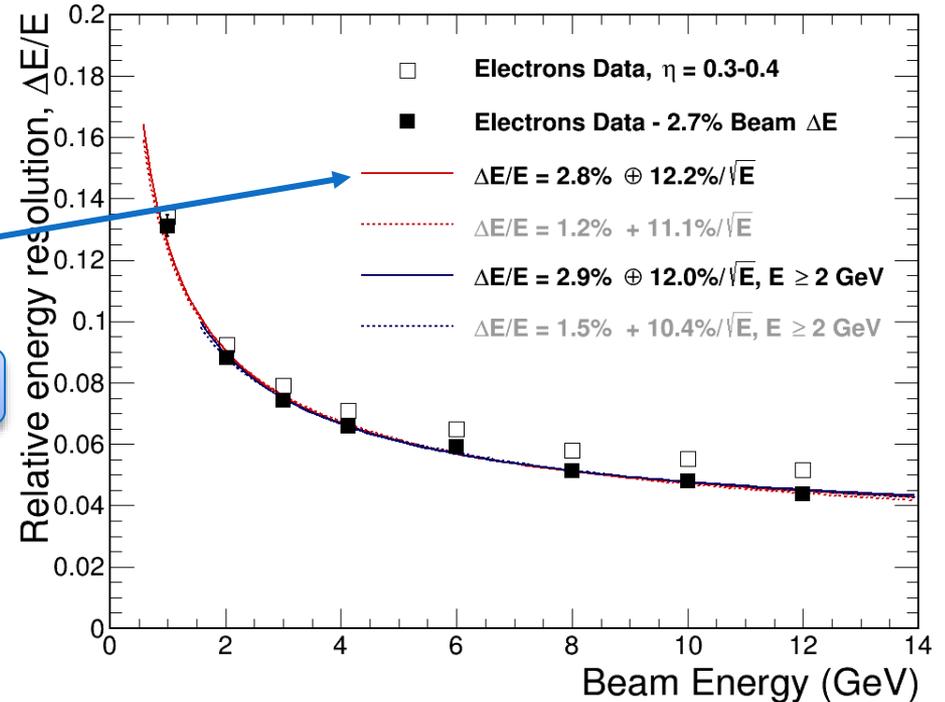
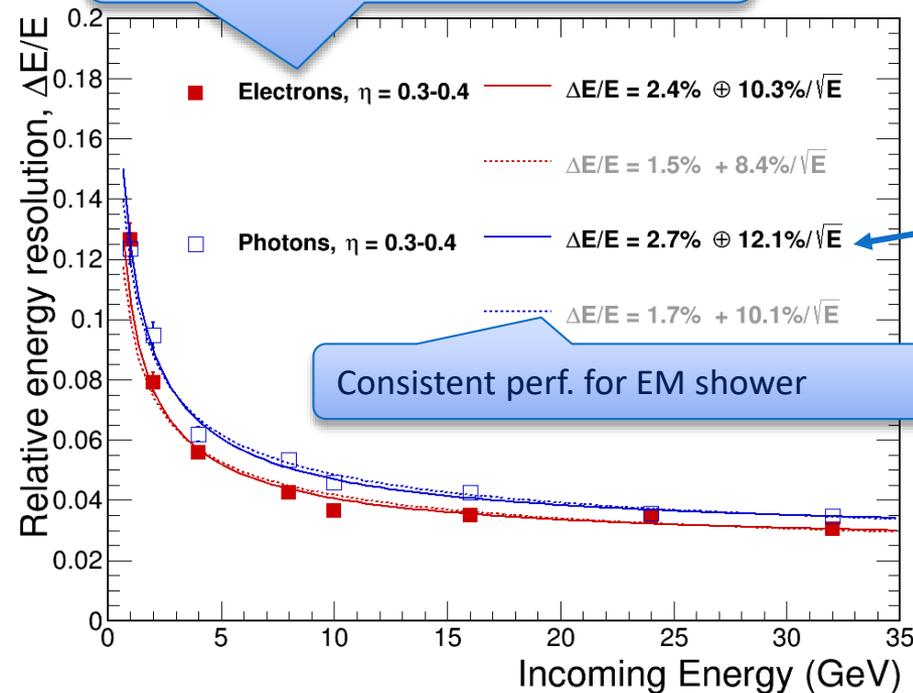
Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe/32MeV), Graph Clusterizer

sPHENIX simulation,
1D projective EMCAL only, full B

1GeV electron is B-bended by 0.45 rad
→ higher SF. and performance

EIC RD1 study

FermiLab beam tests, 1D projective EMCAL

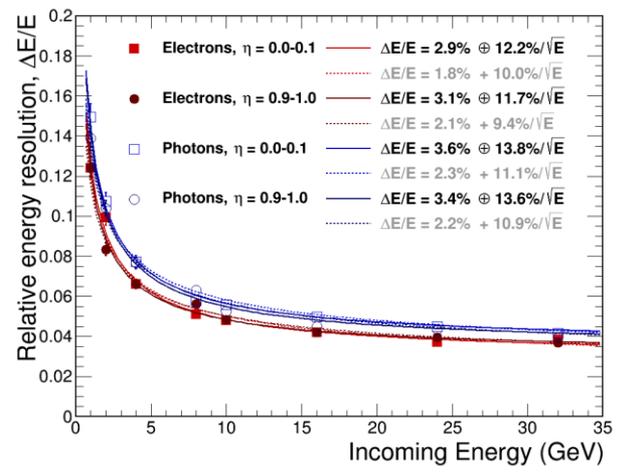
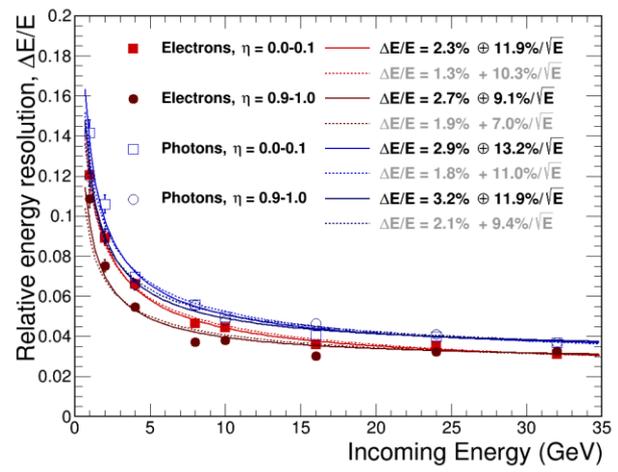
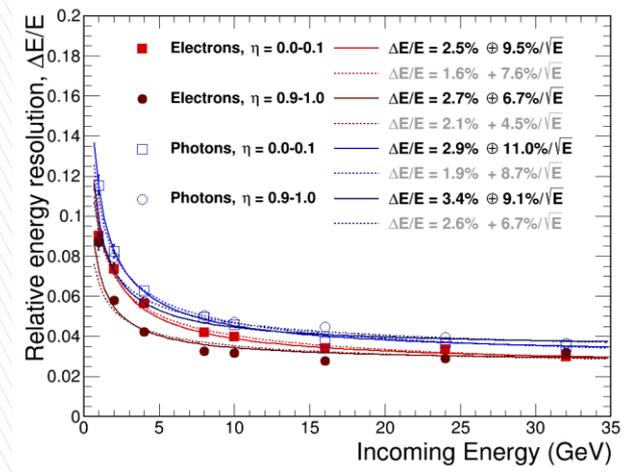
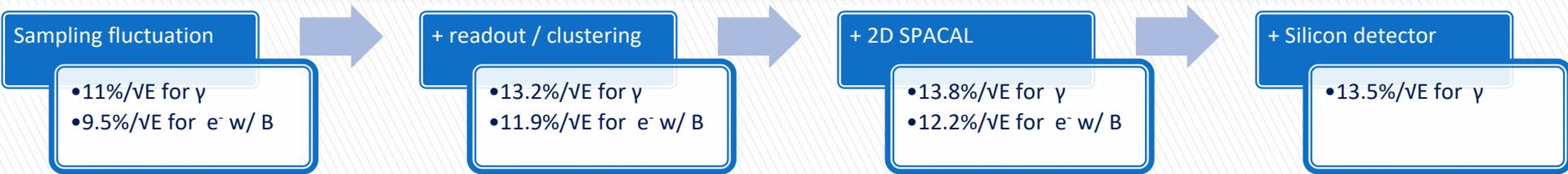


Note difference in range of X-axis

Energy resolution inspections

Simulated on SPACAL without VTX and in full magnetic field

- 1GeV electron is bended by 0.45 rad \rightarrow performance \sim photon w/ eta of 0.45 and view higher SF.
- For EIC, Resolution $\sim < 12\%/ \sqrt{E}$ for electrons after magnetic field bending
- For sPHENIX, Resolution $\sim < 14\%/ \sqrt{E}$ for direct photons



1D SPACAL, No SVX, Sum all tower
No photo-electron fluctuation/pedestal noise

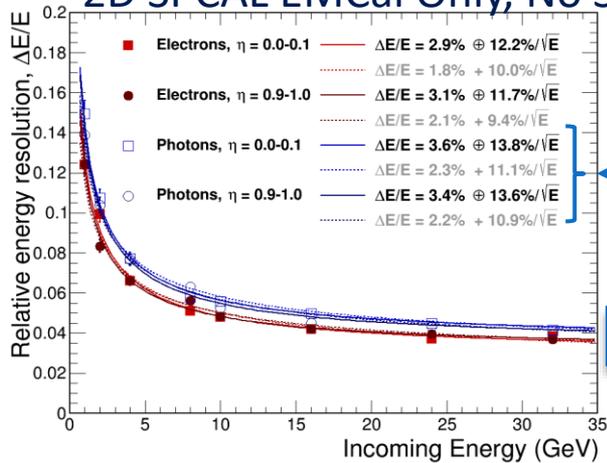
1D SPACAL, No SVX,
Pedestal noise (2ADC), photon fluctuation (500e/GeV)

2D SPACAL, No SVX,
Pedestal noise (2ADC), photon fluctuation (500e/GeV)

Energy resolution for full detector

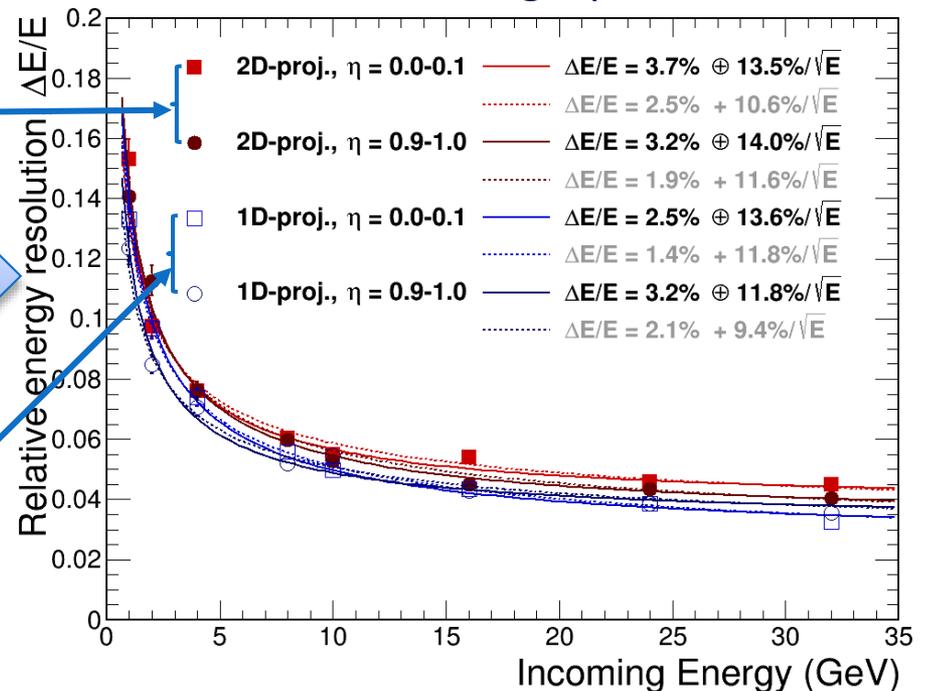
Full detector Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
 Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe), Graph clusterizer

2D SPCAL EMCal Only, No SVX

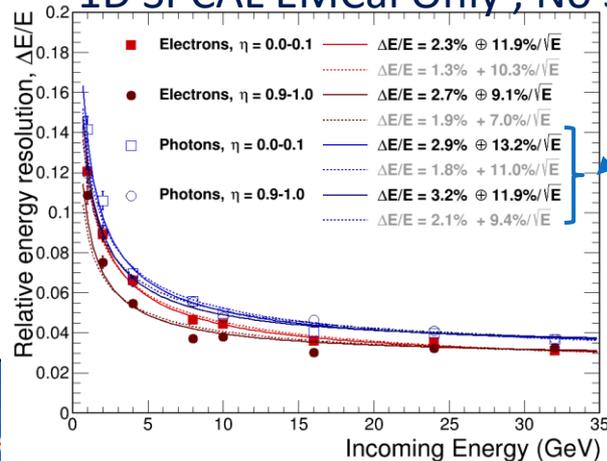


+SVX

sPHENIX full detector single photon simulation



1D SPCAL EMCal Only, No SVX



• Photon performance is similar with full detector (+10% XO SVX before it)

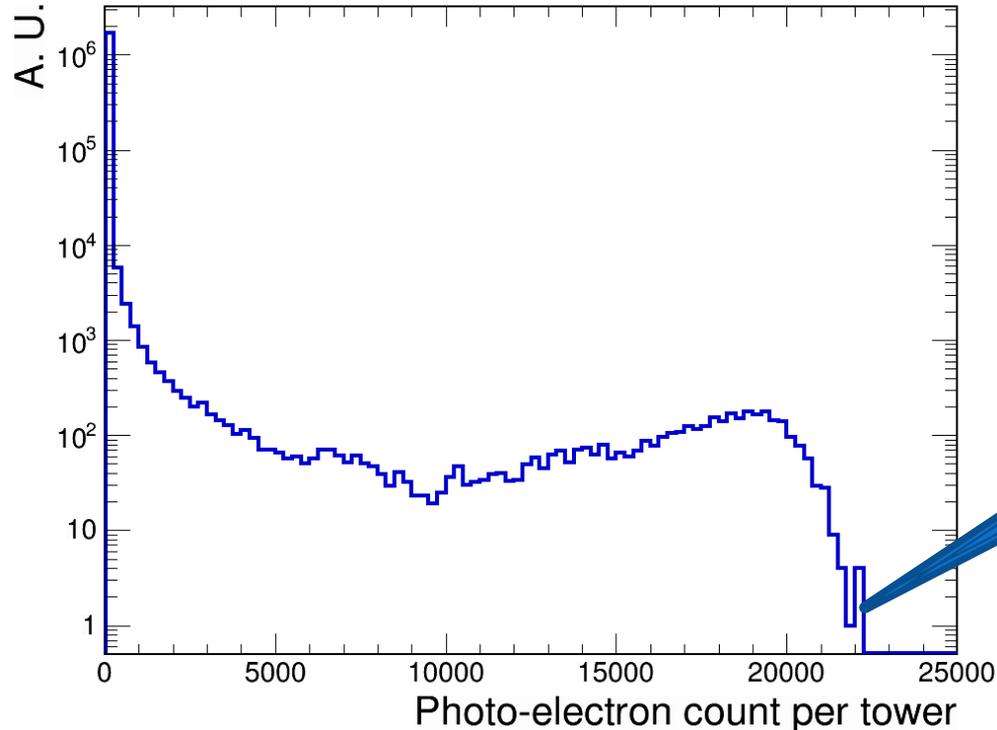


Dynamic range plot

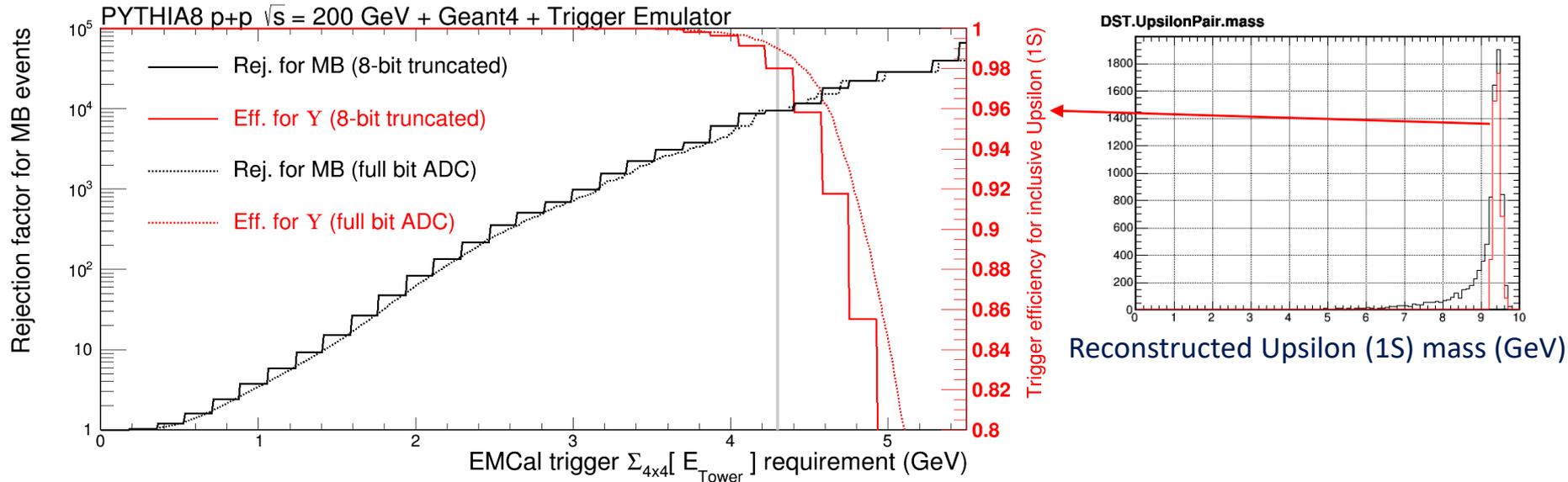
50 GeV photon shower in 2D-projective SPACAL, all eta ranges

Plot photon observed per tower per event,

max $\sim 22\text{k}$ photon/tower, pedestal $\sigma \sim 8$ photon, range $\sim 12\text{bit}$ (max/pedestal 1σ)



Trigger efficiency – 2D SPACAL



Upsilon events required $|\eta_e| < 1$, reconstructed $|\text{mass} - 9.6\text{GeV}| < 2 \text{ sigma}$

Result: $\sim 10^4$ rejection at $\sim 98\%$ efficiency

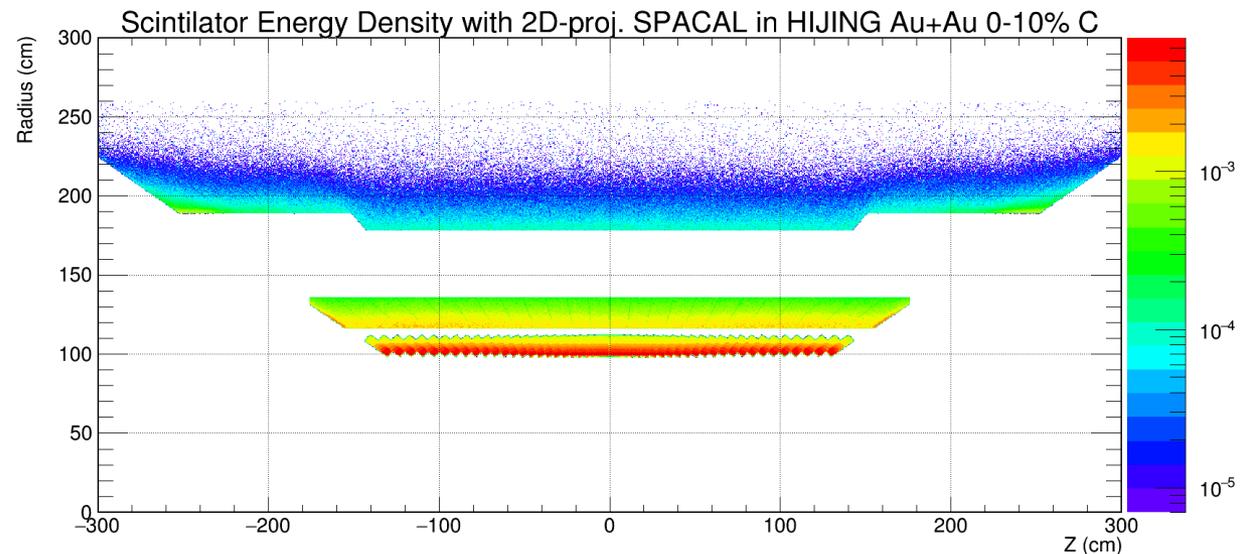
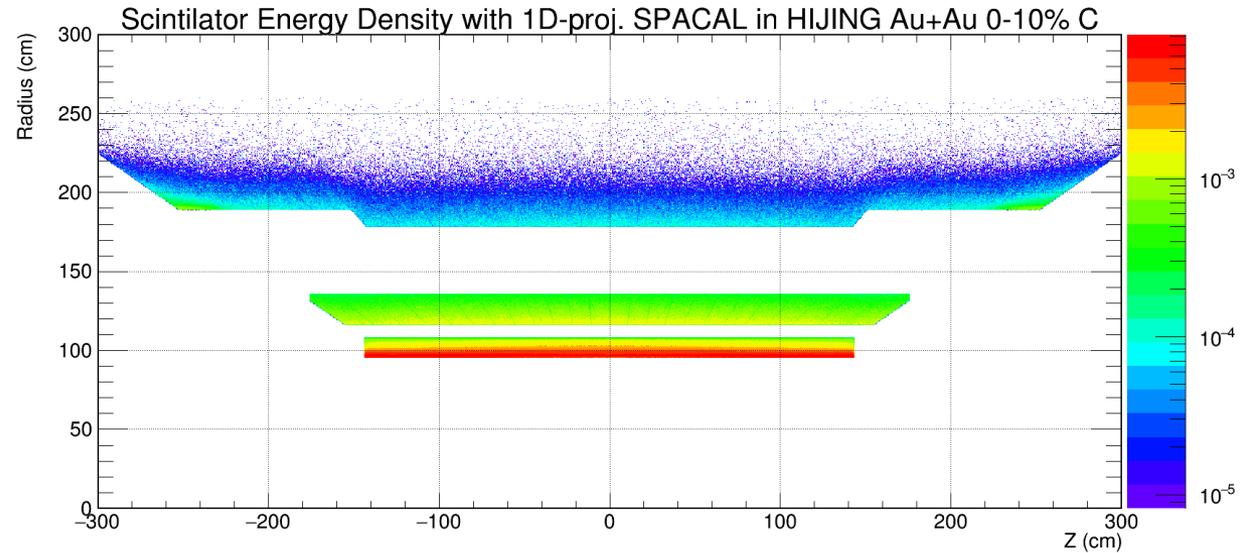
- Tail of Upsilon mass peak excluded for avoiding radiated photon, which are triggered with noticeably lower eff.
- Assumed trigger sum all combination of 4x4 towers, rather than sum of 2x2 \rightarrow 4x4
- Realistic trigger would use reduced ADC bits, e.g. 8-bit. Performance did not significantly changed.
- 2D SPACAL showed. 1D SPACAL required larger cluster at the forward region

Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)

Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe/32MeV), Graph Clusterizer

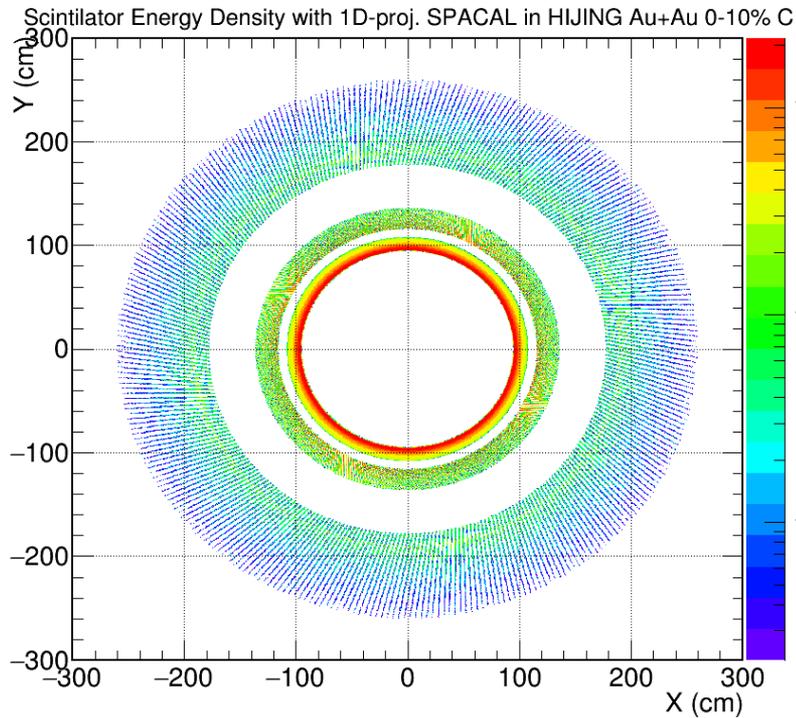
Occupancy in Hijing

- ▶ Volumetric energy density shown

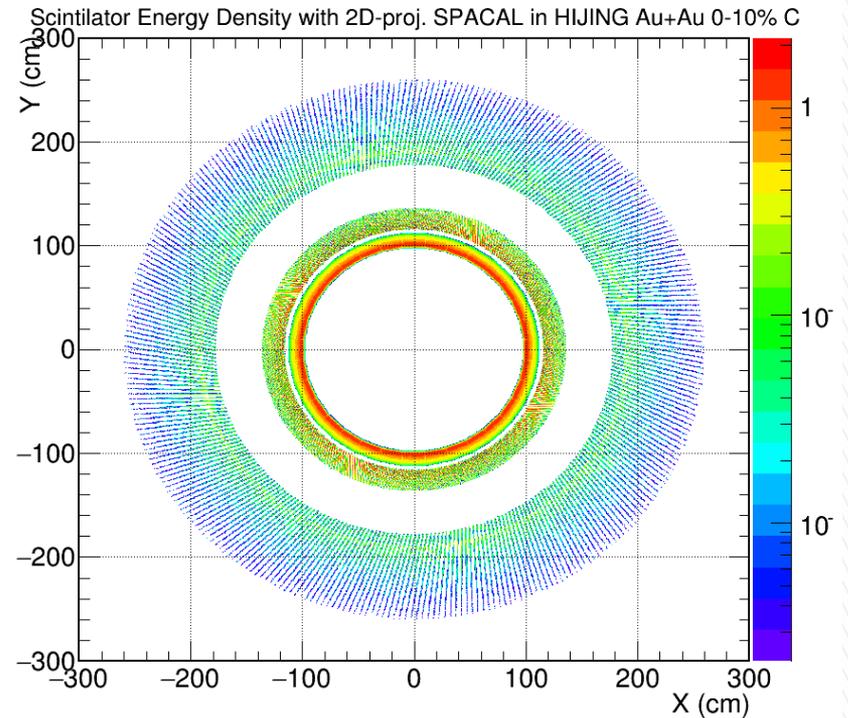


Occupancy in Hijing

2D energy density shown



1D Spacal



2D Spacal

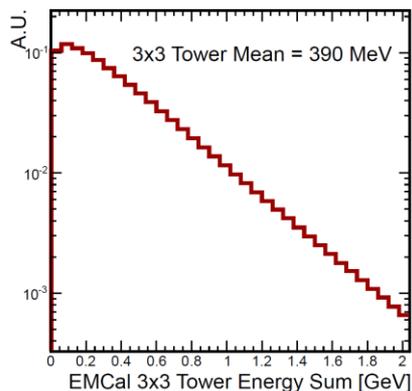
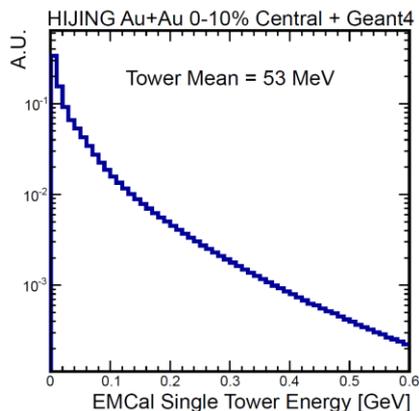
Occupancy – 0-10% Hijing

Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)

Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe/32MeV), Graph Clusterizer

- ▶ Note the zero-suppression at 32 MeV.

Scientific review (no digitalization, 1D proj.)



Realistic tower Digitalization

